WATER INFRASTRUCTURE AND SOCIAL HOUSING IN BOGOTÁ
An intersection between modern water management and social housing production

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RESUMEN

En la actualidad Bogotá afronta la presión de construir viviendas sociales en ecosistemas frágiles, áreas rurales o zonas propensas a las inundaciones, y al mismo tiempo proteger estas áreas para asegurar la capacidad de resiliencia del medio ambiente. Ante esta contradicción, la pregunta de investigación es: ¿Cómo se pueden modificar las tendencias de urbanización para crear una interacción que favorezca el manejo sustentable del agua? Con el fin de responder esta pregunta ésta comunicación presenta un análisis histórico de planes de alcantarillado y control hidráulico desarrollados desde 1990, junto con una revisión de proyectos de vivienda social representativos, e investiga la interacción entre estos dos campos. El análisis permite definir diferentes etapas en la transformación física del sistema hídrico que se basan en los cambios universales de paradigma en la gestión del agua e ilustra diferentes construcciones socio-culturales en torno a la naturaleza, además analiza la producción de vivienda en relación a la transformación del sistema hídrico.

Palabras clave: gestión del agua, vivienda social, Bogotá, urbanismo del agua

ABSTRACT

Currently, Bogotá faces the pressure to continue to urbanize fragile ecosystems, rural lands and flood prone areas with low-cost housing projects and simultaneously protect these areas to ensure environmental resilience. Given this contradiction, the question is how urbanization trends could be reversed into a constructive interplay with a revised water management? In order to that, this paper provides an historical analysis of representative water infrastructure projects, urban plans and housing projects in Bogotá developed after 1900 and investigates the interplays between this two realms. The analysis allows to define different stages in the physical transformation of the water system that are based on universal paradigm shifts in water management and illustrates different socio-cultural constructions around nature. It also analysis the production of social housing in relation to the water system transformation.

Keywords: sustainable water management, social housing, Bogotá, water urbanism

The physical transformation of the water system was a gradual process of landscape domestication to cope with the demands of the urbanization growth transforming the natural water systems and its dynamics. This transformation responds to the change of scale in the city, which grew exponentially after 1930 exhausting the carrying capacity of the landscape. In this paper this transformation is analyzed using archival material from water infrastructure projects, urban plans and social housing projects. The paper intends to discuss three issues. (1) The transition towards a modern "monotechnic" approach to water infrastructure as a result of the expansion in scale. A "monotechnic" approach prioritize technology for the sake of technology progressively eliminating biological diversity and socio-cultural uses (Mumford 1934). This approach was question under the paradigm shift of sustainable water management that advocates for the return of a "polytechnic" approach that provides a complex framework to solve human and environmental needs. (2) The conflict that arise from the transformation of the natural systems in artificial elements. This conflict basically resulted from the transformation of the water system in linear elements disregarding their intrinsic logics as dynamic systems and fields. (3) The implications of the water system transformation at the scale of the social housing tissue and vise versa. The basic interplay between water management and urban tissue is related to the way in which urban areas are integrated within the water cycle, and its spatial relation the water context. (Novotny 2009). Contemporary measures to restore the water cycle focus on storm water management, water recycle and reuse, integrating landscape elements within the urban structure. In the projects presented in this paper the intersection the interplay is analyzed mainly through the understanding of the storm water management, the infiltration capacity of soil in relation to the urban form and the water context.

1 HIDING FLOWS AND URBAN BEAUTY

1.1 Pre-modern water management and the redefinition of nature

Bogotá population grew slowly until the end of the 19th century. By 1880, the city reached the highest average density in its history with 400 persons per hectare (IEU, 2014). The high density and lack of appropriate sanitation infrastructure created serious health problems. The concerns about public health intensified after the pandemic Flu of 1918-19. This made even more urgent, not only the need for modern water infrastructure, to plan urban growth and to create housing regulations and institutions for the construction of dwelling units for working classes. The first sights of modernization in Bogotá are indicated by the introduction of international technical approaches of hard engineering that dominated water management during the nineteenth and twentieth century (De Meulder & Shannon, 2013).

The first water infrastructure plans introduced a transition towards a mono-technic approach to water infrastructure. The transition is the result of the increase of density and personal water consumption after the construction of the first aqueduct for water supply in 1888. The first water infrastructure study was developed by the firm S. Pearson and Son from London in 1907 and complemented by Ulen & Co from New York in 1917. Both studies focus in the already urbanized area, proposing a combined underground sewer system and water treatment before discharging into the rivers (EAAB, 1970). In 1927 a new study was developed by the firm J. G. White Engineering Corporation from New York including not only the urbanized area but also the land for future development (Fig. 1). The plan followed partially the extension proposed by the Bogotá Futuro Plan (1923-1925) design by Enrique Uribe. The sewer system follows the structure of the road system which is basically a grid only intersected by the rivers.

Bogotá Futuro Plan, is the first modern urban plan for Bogotá. It emphasized themes of sanitation, transport, urban development and legislation (Alba, 2013). The plan was develop for a future population of 800,000 inhabitants and had three main aims: hygiene, comfort and beauty (Alba, 2013). The plan proposed modern roads, large parkways, boulevards, ring roads, and also the use of the river system for beautification purposes. Modernization ideals through the construction of sanitation infrastructure were accompanied by new energy sources, modern markets, tram lines, and cheap working dwellings units with natural light and ventilation in neighborhoods structured by squares and parks (Alba, 2013).

This first modernization attempts contrast however with the growth of informal areas. Due to the manufacturing development, informal areas for working class expanded along streams and other city areas, around factories, quarries, mines and tanneries, maize liquor and food shops (Serna & Gomez, 2012). The central location of these areas foster development interests placing them in the center of the discussion about future re-development. During the pandemic Flu the health issues related with the built environment became even more critical.

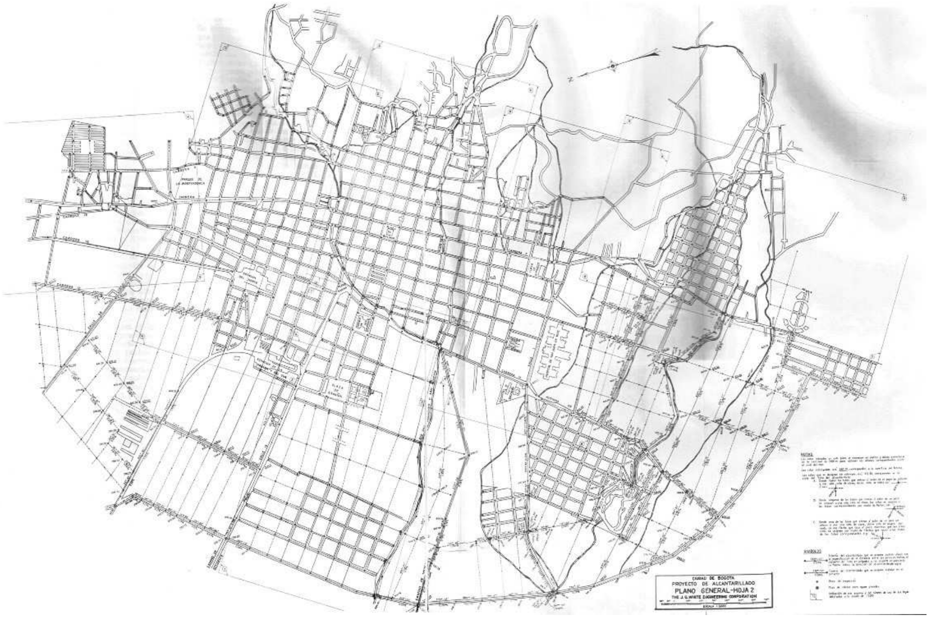

Fig. 1. Sewer system project J. G. White Engineering Corporation, 1927
(EAAB 1970).

The Bogotá Futuro Plan was never implemented. After this plan, Karl Brunner elaborated a development plan mainly based on the addition of neighborhoods (ensanches) that gave continuity to the urban tissue through the extension of the grid. The grid is distorted to create variations in the tissues, squares, boulevards and parks or in response to natural elements. For instance in the study for an extension in the south of Bogotá, a green corridor along the San Francisco River contains public facilities, schools and sports club (Fig. 2). In the project the river is a left a void that interrupts the continuity of the tissue and function as collector of public facilities. There is a clear opposition between the artificial quality of the grid and the natural river course.

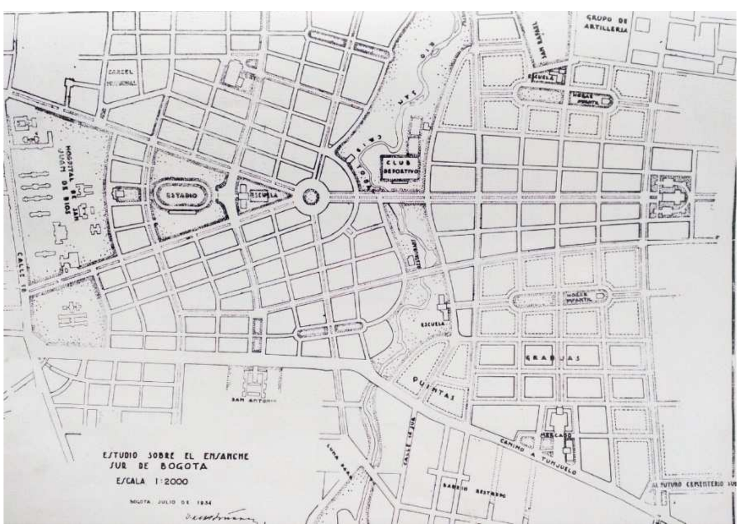

Fig. 2. Study for an extension in the south of Bogotá, Karl Brunner, 1938
(Brunner 1939/40).

1.2 Social housing and sanitation

Bogota development Plan of Brunner (1933-1938) incorporated various projects that were proposed as part of the "Centenario" program. The program was set in order to celebrate the fourth centenary of the city founding and included the sanitation of the Paseo Bolivar (transforming this area occupied by informal settlements in a park) and the construction of a working district “Barrio Centenario” for the resettlement of population (Hofer, 2003). These projects illustrate the relation between sanitation, city beautification and social housing in the first part of the twenty century. The Barrio Centenario was supposed to provide an integral solution to housing, in which the State took charge of delivering finished dwelling units. The neighborhood was not connected to the public service network, depending on the proximity of the Fucha River for water supply. This proximity to fresh water supply determined the location of social housing projects and urban development until the 1930s when the water supply network expanded.

The basic layout of the Barrio Centenario, consists on a grid that generates square plots (Fig. 3). A house, subdivided in four dwelling units, is located at the center of each plot. The proposal included areas for small orchards intended to provide self-sufficient food supply, shared laundry and public facilities. Brunner considered that an adjacent garden was not only a hygienic requirement but also a socio-economic necessity for modern population (Pulgarín, 2009). Storm water is used to irrigate the orchards or infiltrated on the ground. An existing wetland was preserved as a park. Originally the project was not connected to the main sewer network. Therefore waste water was probably directed towards the existing water bodies.

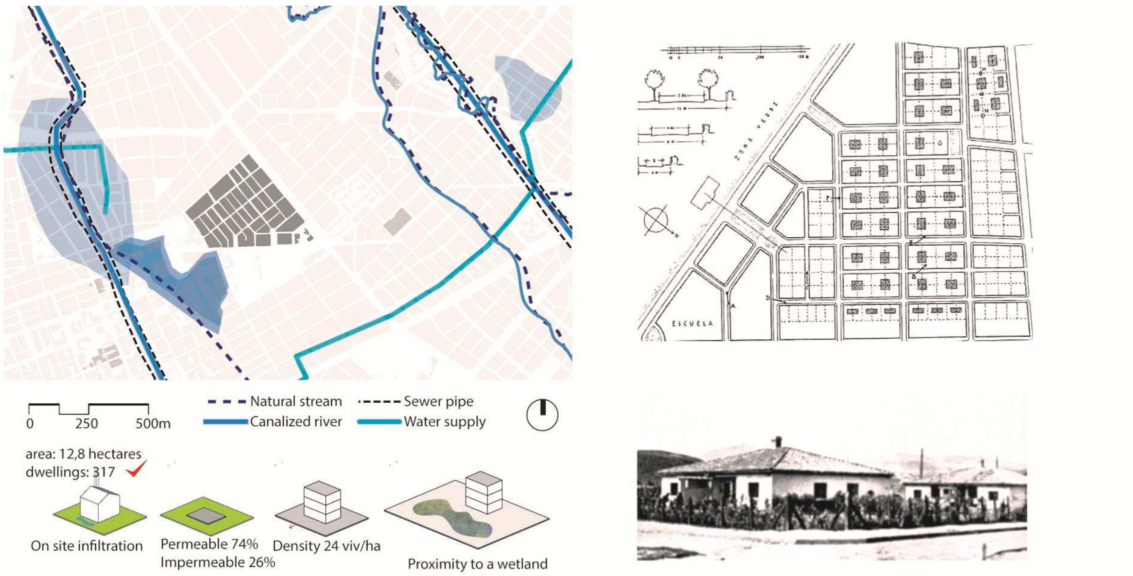

Fig. 3. Plan Barrio Centenario, Karl Brunner, 1938
Left Elaborated by the author. (Brunner 1939/40).

The development plan of Brunner and the Bogotá Futuro Plan shared similar concepts regarding the preservation of the water system as a recreational asset that indirectly implies a multipurpose approach that preserves ecological value and manage naturally storm water. This approach contrast with the proposal of the first sewer system that convert the rivers in main axis of drainage.

Brunner’s works in Bogotá illustrate three different interpretations of nature. First, nature is redefined as an urban artefact through the design of boulevards and parks. Second, nature is integrated as an asset for aesthetic purpose by interweaving it within the urban fabric (the green corridor along the San Francisco River). Third, nature is recognize as part of an organic continuity by introducing productive orchards in the social housing projects. Brunner’s urbanism handbook (1939-1940)[1] contains a specific section titled “rivers and canals”. In this section he highlighted the importance of preserving rivers and streams open wherever feasible and stated that the transformation and improvement of river banks must be a task within the urbanism practice, especially for beautification and functional uses related to water transport (Brunner, 1939).

[1] Brunner´s urbanism handbook (Manuel de Urbanism) is a compilation of recommendations in three volumes. The first addresses the issues of sanitation and urban housing and the second deals with urbanization and road infrastructure and the third (unpublished) with zoning, green spaces, airports, art and urbanism.

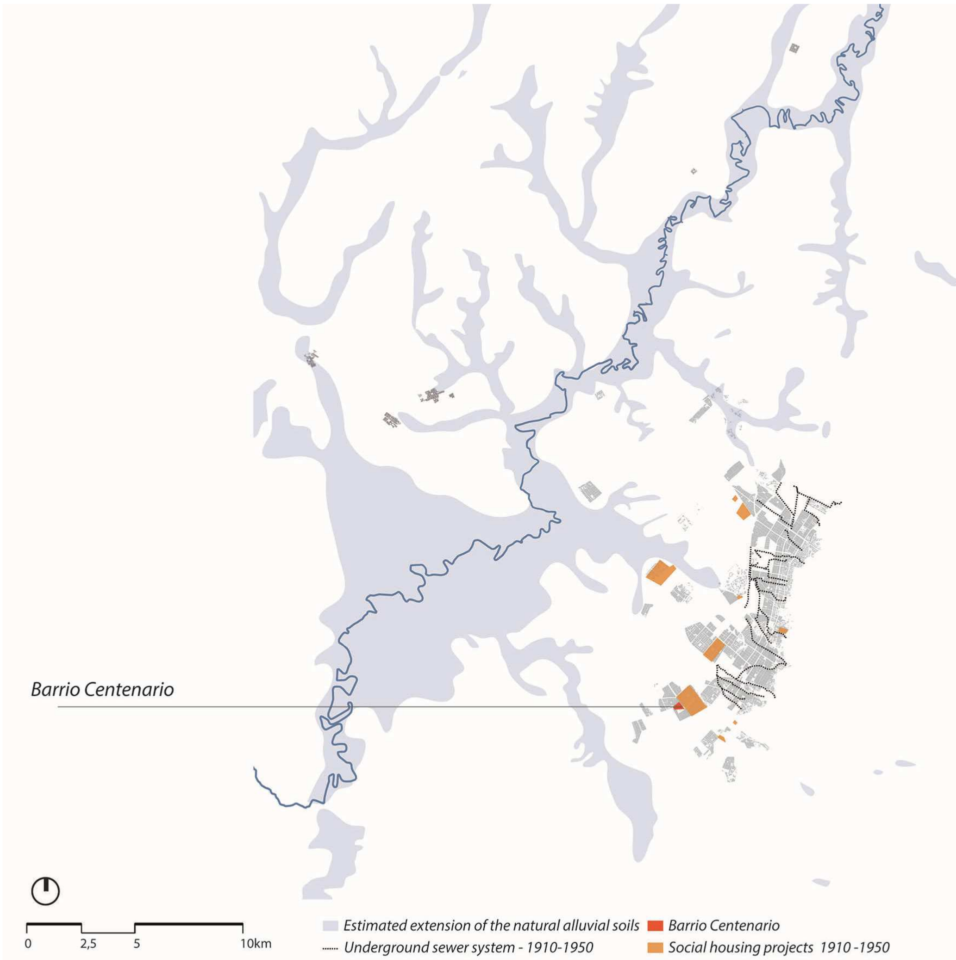

Fig. 4. Social Housing production and water system transformation 1918-1950.
Elaborated by the author based on Saldarriaga, 1966; Van Der Hammen 1998; Ideca 2015

2. REDIRECTING FLOWS

2.1 Modern water management. From dynamic systems to lineal elements

After 1940s the intense political conflict forced internal displacement, coupled with population growth, made even more urgent to plan future development (Torres, 2011). It is also a period of huge economic growth, this accumulation of economic means allowed the implementation of large scale technical solutions for water management, and the massive support of urban planning construction of social housing. The discussion around the modernization and future of Bogotá started to involved different professional associations and academics (Castillo, 2008). As a result in 1947, Le Corbusier is invited to Bogotá by the major Fernando Mazuera following a suggestion made by the Colombian Society of Architects. After the visit he is hired to develop a master plan for the city together with Paul Lester Wiener and José Luis Sert, creating the office for the Plan Regulador in 1948 (Castillo, 2008). Regarding to the water system, the Plan Regulador introduced the concept of green structure, which was mainly an afforestation strategy along the rivers in which "modern" nature was constructed through the planting of trees. The principle operates at different scales, from the dwelling unit in which trees form the counter- figure of the architecture, urban parks coupled with cultural activities, to the regional scale in which the green structure forms the counter-figure of the city, providing a framework for the countryside, which is used for weekly recreational activities of urban inhabitants (Le Corbusier, 1950).

In 1952, the firm Buck, Seifert & Jost, based in New York, was hired to elaborate a preliminary basic study for the most efficient and economic method for collection and treatment of waste water in Bogotá according to the Plan Regulador. The study recommended the construction of separated sewer systems in new areas, gave basic standards for hydraulic design, (although warning the importance of calculating according to local data), proposed alternatives for the distribution of the network, and highlighted the need to define the areas with waste water collection pipes or "sanitary district", taking into account possible future developments (Buck, Seifert & Jost, 1952). These recommendations were the base for the Master Plan for Bogotá Sewer System of 1962 developed by Camp Dresser & McKee, Inc. "CMD" from Boston and Compañía de Ingeniería Sanitaria "CIS" from Bogotá (Fig. 5). The Master Plan of 1962, originally designed for an estimated population of 3.5 million, defined the main layout of the current water system. (CDM, 1962). At this time population of 1'697,311 already has exceeded the projections made by the Plan Regulador of Le Corbusier. Hence, the architect Germán Samper was hired as a consultant to elaborate an updated assessment of urbanization trends that guide the design of the network capacity.

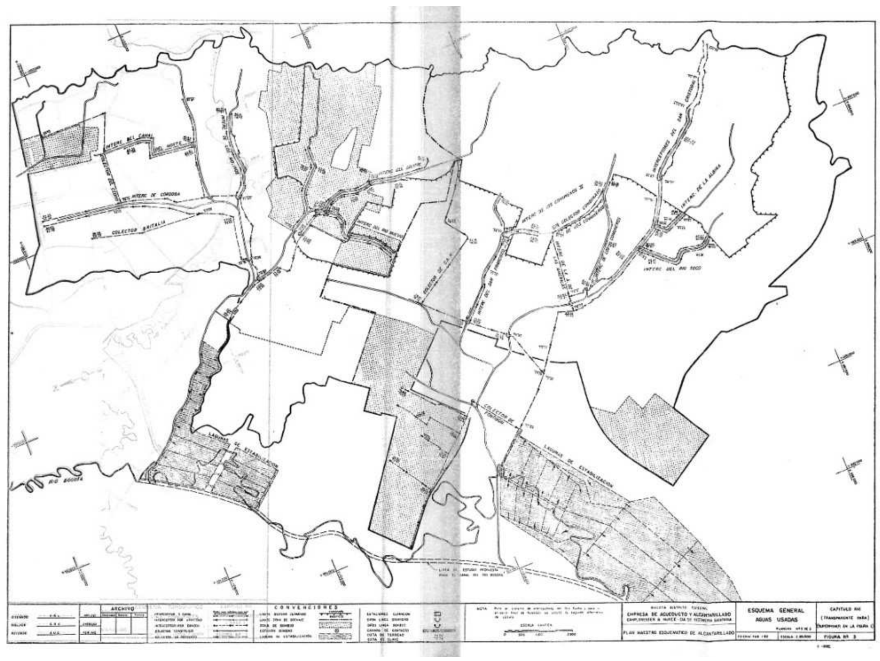

Fig. 5. General scheme for the sewer system. EAAB, CDM & CIS, 1962.
(CDM, 1962)

The plan established two main objectives in addition to the management of run-off. First, the protection against waterborne diseases through the elimination of microorganisms. Second, the elimination of smell produced by the decomposition of organic solids (CDM, 1962). Basically the master plan proposal is an attempt to control the flows of water that cross the city and to create a deodorized environment proper to modernity[2]. In the plan the complete natural system is transformed in a linear and hierarchical system[3].

The jump in scale implied the transformation of the water system in a complete mono-technical infrastructure. Although the rationalization of the water system took partly advantage of the natural conditions of the place. The natural drainage defined the structure of the main sewer network and natural process were proposed to treat the polluted water. For instance, stabilization lagoons are low-cost alternative for waste water purification that capitalizes on natural processes and low-tech techniques of simple pumps and gravity, therefore they can be considered a "soft-engineered" approach to water management (Shannon, 2008). However, the large scale of these elements would have made impossible to integrate them with other urban functions. The materiality of the water network results in a mono-functional system of storm water collection, which contradicts the recreational or aesthetic programs projected by the Plan Regulador of Le Corbusier.

[2] The clear emphasis on the importance of eliminating the discomforts produced by the bad smells was also mentioned by the plan of 1952. According to this plan, the use of waters bodies for the disposal of waste water cannot be considered "rational" or acceptable if it creates disadvantages for the public, which means if it annoy the senses of a normal man o constitute a potential thread for the health of the neighboring residents (Buck, Seifert & Jost 1952).

[3] The main drainage network follows the natural drainage of the city. In technical terms, storm water from the mountains was intercepted upstream and redirected to sewer network. In the area with a combined sewer system, water flows were redirect to chlorination stations. In the area with separated sewer system, water flows were decoupled in two systems, storm water collected and redirected to the main rivers that were transformed in open canals, and waste water transported by underground pipes (parallel to the river courses) to the chlorination stations. From the chlorination stations, wastewater could be treated in stabilization lagoons that use the intensity of the sunlight and temperature to remove pathogens and nutrients. It was also estimated that every 6 to 8 years the sludge need to be removed from the lagoons and it could be used for agriculture purposes after drying (CDM, 1962).

The plan was divided in four phases, the first two phases of the plan were completed between 1967 and 1971, solving the main structural lines for the collection of waste water within the sanitary perimeter (Fig. 6). Some of the works proposed for the third phase were included in the “Plan Maestro de Alcantarillado y Programa Integrado de Desarrollo Urbano Zona Oriental” of 1975 (EAAB, 2003). The last phase consisted in the underground sewer pipes between the sanitary perimeter and the Bogotá River and the treatment for waste water. This was not completely built, therefore the low section of the tributary rivers and the Bogotá River are highly polluted.

Fig. 6. Master Plan for Bogotá Sewer System. Phases of implementation. EAAB, CDM & CIS, 1962
(CDM, 1962)

Fig. 7. Works built by the Empresa de Acueducto y Alcantarillado. Saul Orduz. 1973
(Museo de Bogotá, 2015)

In the Plan Regulador of Le Corbusier a “modern” nature was constructed through the planting of trees along the main tributaries (Fig. 8). With the implementation of the Master Plan the rivers were transformed from dynamic systems to lineal elements, and this functional transformation was accompanied by the replacement of the word “river” by the word “canal” that was systematically used to named natural and artificial structures. This semantic change not only encapsulates the functional transformation of the water system but also expresses a detachment between people and landscape which is proper of the modern relation between nature and society in which water was to a large extent de-symbolized (Fig. 7) (Shannon, 2013).

In his study of Paris Haussmanization Gandy states that the transformation of the water system manifest a process of “redefining nature”, which is mainly the result of the “loss of organic continuities of pre-modern nature”. By burring the circulatory systems nature is redefined by parks, boulevards and trees and the previous organic continuities are broken (for example the use of human excrement as fertilizers for agriculture that integrated bodily functions into the regional economy) (Gandy, 2014). In Bogotá the process of redefinition of nature was incomplete. The transformation of the rivers in concrete canals was built but the vision of the river system as green structure remained only as a concept. Modernity transformed nature in a hybrid system that works as a modern artefact. Despite the shortcomings of this hard engineering scheme, an intelligent decision was to assume the high investment costs necessary for the construction of a separated sewer system. This provide opportunities nowadays to intervene the water cycles.

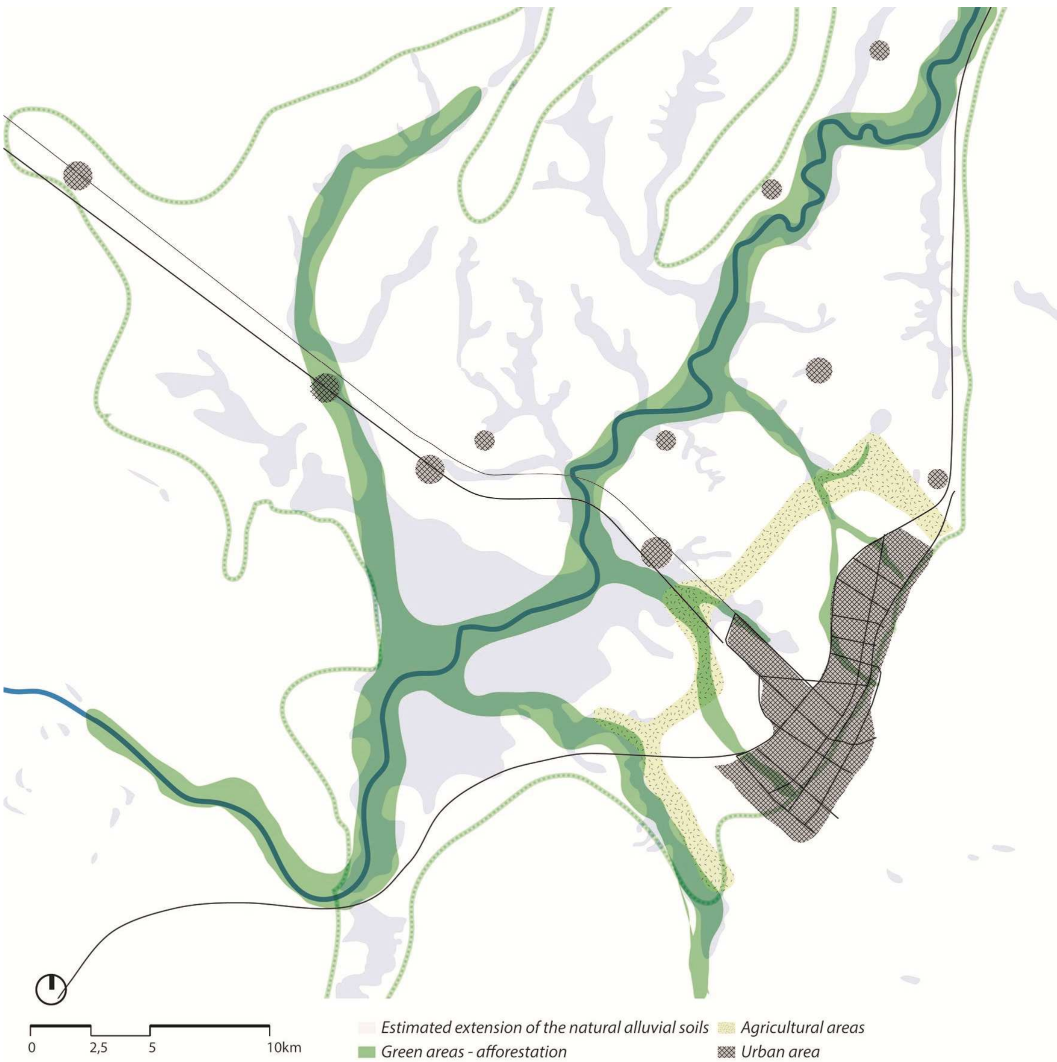

Fig. 8. Regional Plan. Plan Regulador by Le Corbusier
Elaborated by the author based on Le Corbusier, 1950.

2.2 Massive social housing production

In the parallel to the development of urban plans and infrastructure, social housing production between 1943 and 1965 was also massively provided by the State (Fig. 9). In this period there was constant experimentation in terms of urban design, architecture typologies, construction techniques and production schemes. The variety of the production include single family houses in individual plots, multifamily housing complex with common facilities, site and services schemes and incremental self-built housing. However, there was not an overall program for social housing construction but rather the addition of individual projects developed by the different housing institutions (Saldarriaga, 1996). Urban expansion was characterized by a discontinuous growth of urban fragments that were not necessarily articulated to the road network. The extension of the water supply and the possibility for future connection to the sewer system, within the limits of the sanitary district, provided a platform for urbanization detached from the landscape. Some of this projects were built in rural peripheral areas and stimulated the expansion of urbanization.

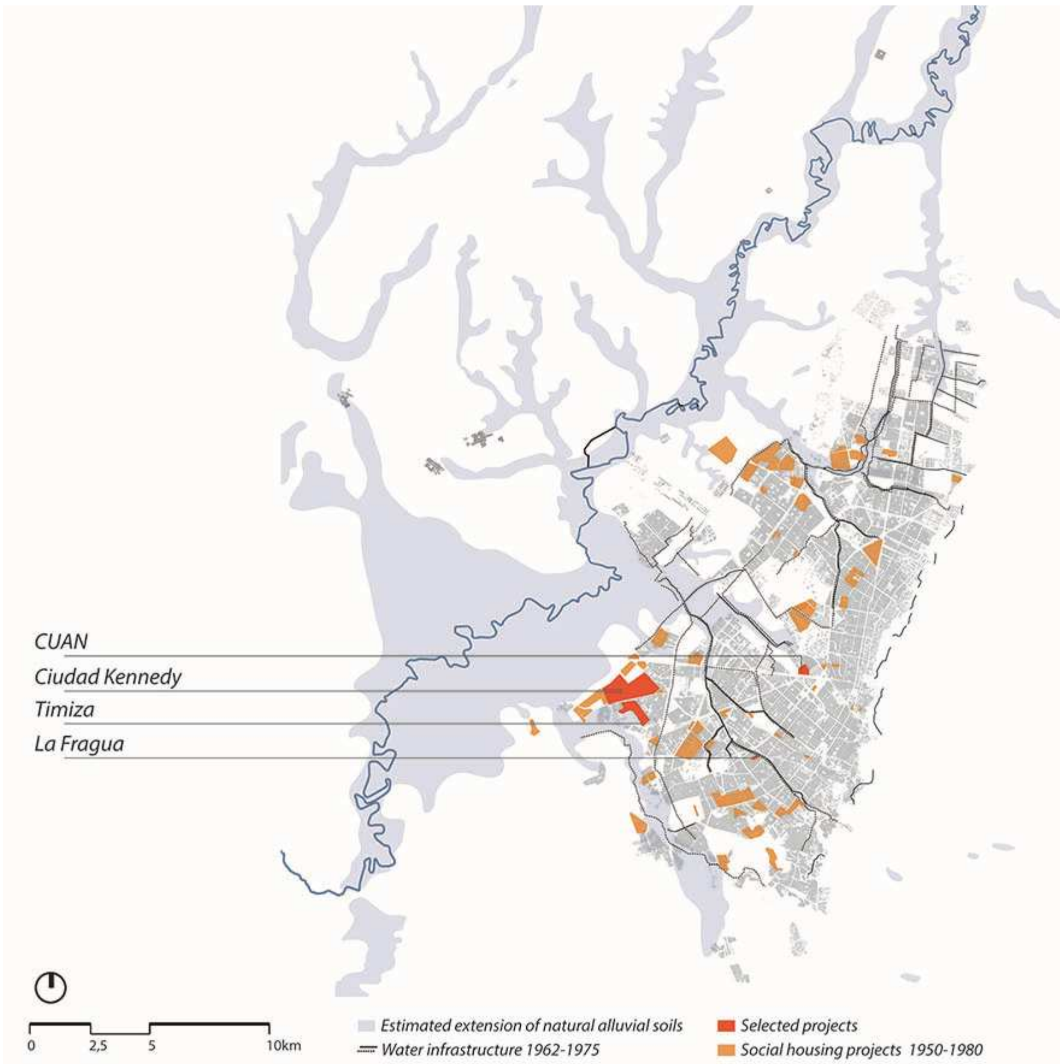

Fig. 9. Social Housing production and water system transformation 1950-1990.
Elaborated by the author based on Saldarriaga, 1966; Van Der Hammen 1998; Ideca 2015; CDM 1962

The variety of institutions and schemes resulted in diametrical opposed schemes that represent different local interpretation of modern ideals. Within the long list of social housing projects it is worth to mention the Centro Urbano Antonio Nariño (CUAN) promoted by the ICT (Instituto de Credito Territorial) in 1951 (Fig. 10). In the project designed by Néstor B. Rodríguez y Esguerra, Saénz, Urdaneta, Suaréz & Cia., the architects adapted the model of the "Unité d'Habitation" to the requirements of Colombia. The footprint is only 11% of the plot of 14,5 hectares occupied by 14 housing blocks of 4 and 12 stories that provide 768 dwellings for 3000 inhabitants, organized around a large park area and 8 buildings for communal services (theater, supermarket, laundry, school, church and recycling plant) (Castilllo, 2008). It is the first and unique example of a high rise housing complex in Colombia conceived as an autonomous unit that stands out a

State´s attempt to modernize society through architecture and urbanism. Green areas provide large capacity of infiltration. Underground pipes represent the "modern" construction of nature in which water became an infrastructural grid.

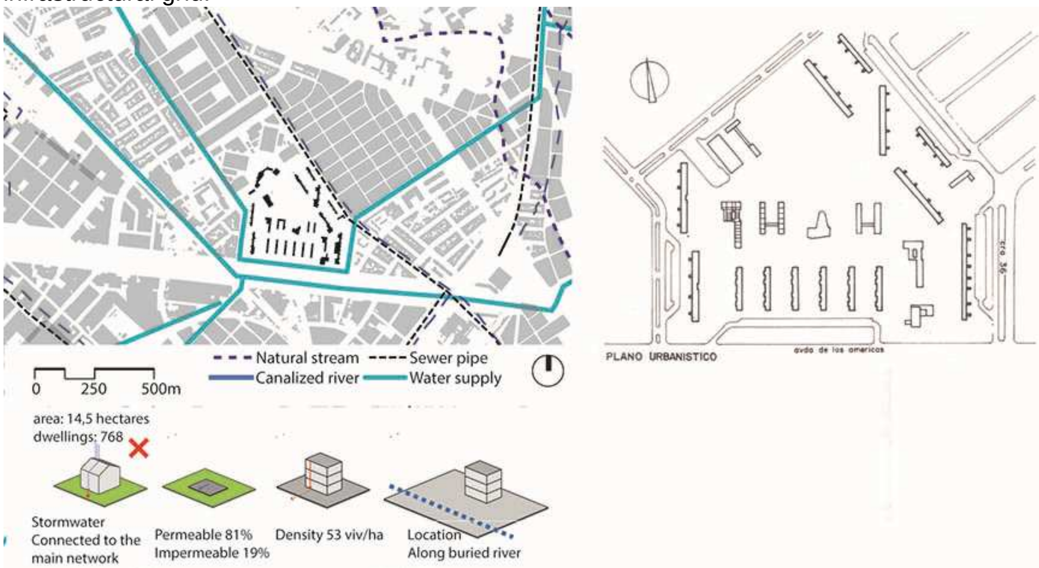

Fig. 10. Centro Urbano Antonio Nariño (CUAN) 1951.
Left, elaborated by the author. Right, (Castillo 2008).

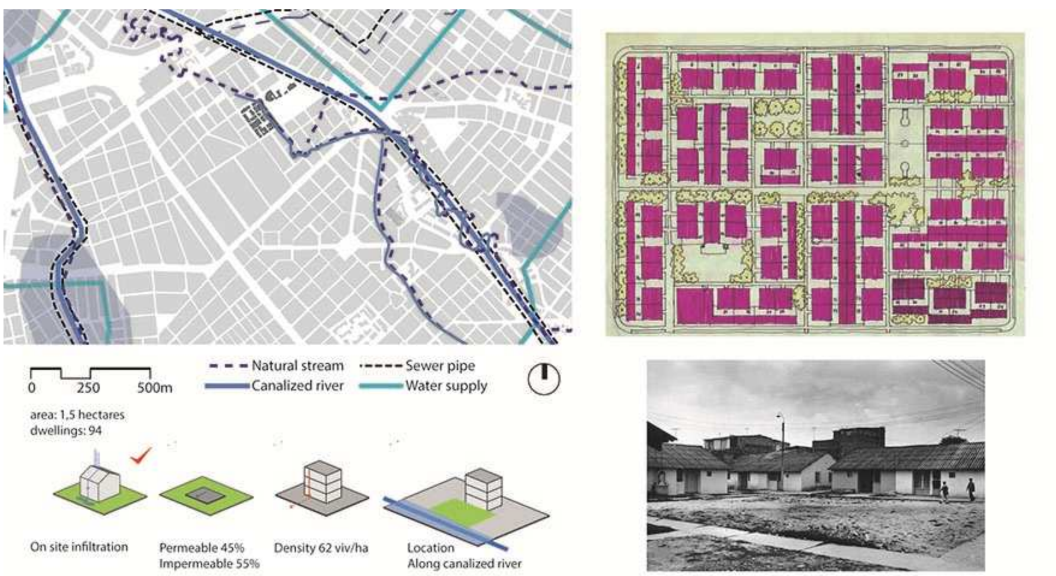

Fig. 11. La Fragua, 1954.
Left, elaborated by the author. Right, (Samper 2012).

The neighborhood La Fragua presents a diametrically opposed response to the housing problem, being one of the first experiences of self-built housing in the country (Fig. 11). The project, designed by German Samper, is conceived as a "community residential unit" (unidad residencial comunitaria). The Centro Interamericano de Vivienda (Cinva) provided technical support during the self-help building process, the State provide financial and technical support through the ICT and the community invested its labor force. The proposal is located in proximity to a canalized river. River canalization not only allowed to evacuate run-off faster but also created more space for development by reducing the floodplain. The low-rise high-density housing model for 94 dwellings is organized through a network of pedestrian roads and public spaces in a plot of 1.5 hectares. The housing typology is flexible and can grow incrementally according to the economic capacity of the inhabitants. (Samper & O´Byrne, 2012). The urban layout favored the size of the plot, reducing public space to its minimum. Incremental growth increased density and impermeable surfaces

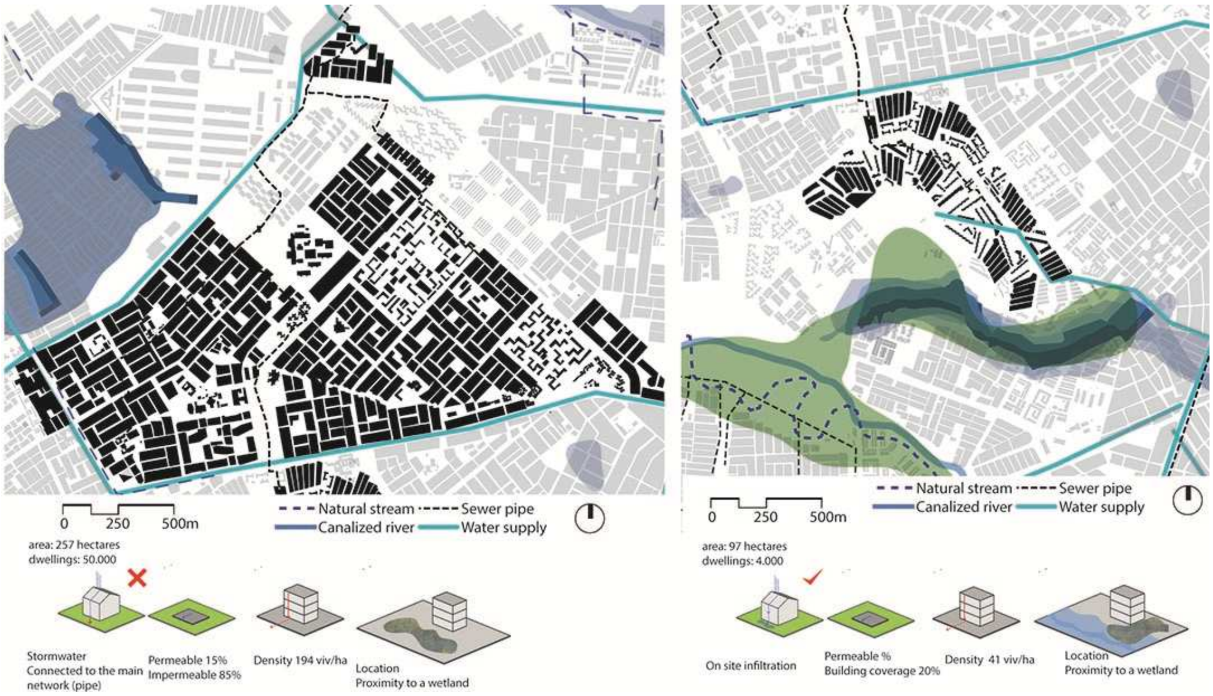

Fig. 12. Ciudad Kennedy, 1960. (Left) Timiza, 1966. (Right)
Elaborated by the author.

Large programs of self-built housing based upon new techniques of “esfuerzo propio” (self help) and “ayuda mutual dirigida” (directed mutual-aid) were also incorporated by the ICT since 1958 to provide solutions for low income population that was usually excluded from existing programs. Such techniques require the organized investment of future occupants’ spare-time, as well as their accumulated savings. One the largest self-help housing project ever undertaken in Latin America is Ciudad Kennedy (Fig. 12). This project has an area of 257 hectares and 50.000 dwellings. The urban design combines different housing typologies in large blocks with pedestrian circulation. The project is located at what was before the edge of the Bogotá River floodplain, in proximity of a wetland that was later drained. Its construction boosted the expansion of urbanization on the floodplain. The sewer networks were included within the Master Plan of 1962.

This period is also characterized by a high quality urban and architectonic projects, for instance Timiza in 1966 (Fig. 12), Pablo Sexto in 1966 and also “experimental projects” among them Kennedy experimental and Tunal experimental. Timiza, designed by Rogelio Salmona and Hernan Vieco, has an area of 97 hectares and was designed to provide 4000 dwelling units (Goossens & Gómez, 2015). The urban layout is organized around a large-scale park which preserves a wetland (later converted into a lake) that is part of the natural system of the Tunjuelito River floodplain. This project is the first that uses landscape elements as a design asset. Pedestrian circulations are oriented towards the body of water and rainfall in infiltrate on site. Different housing typologies, five stories blocks and two story houses with garden, are combined within an organic layout.

In general, the projects are inserted within the infrastructural network of underground pipes that was designed in the master Plan of 1962. The mono-technical approach to infrastructure at the local scale is represented by the lack of integration of the water bodies within the urban layout. Timiza is the only example in which storm water, recreational uses and urban morphology converge.

3 TAMING THE FLOODPLAIN

3.1 Modern water management. From river systems to water or land

The water management plan of 1962 created an infrastructural layer instrumental for the development of the city. However, as the city grew water issues were displaced outside the artificial boundary defined by the sanitary perimeter. Thereby flood control of the Bogotá River and water management at the regional scale became the focus of the water management plans after 1973. These studies considered the Bogotá River is a resource that could be improved in order to create land for development. Therefore, reducing the river system to the category water /or/ land.

The first study was elaborated in 1973 by Camp Dresser & McKee, Inc. CMD from Boston and Compañía de Estudios e Interventorías and Planhidro Ltda from Bogotá. This study was elaborated in coordination with the urban plan "Estudio de Desarrollo Urbano Fase II". This plan is the first to tackle the complexity of the water management in the region (Fig. 14).

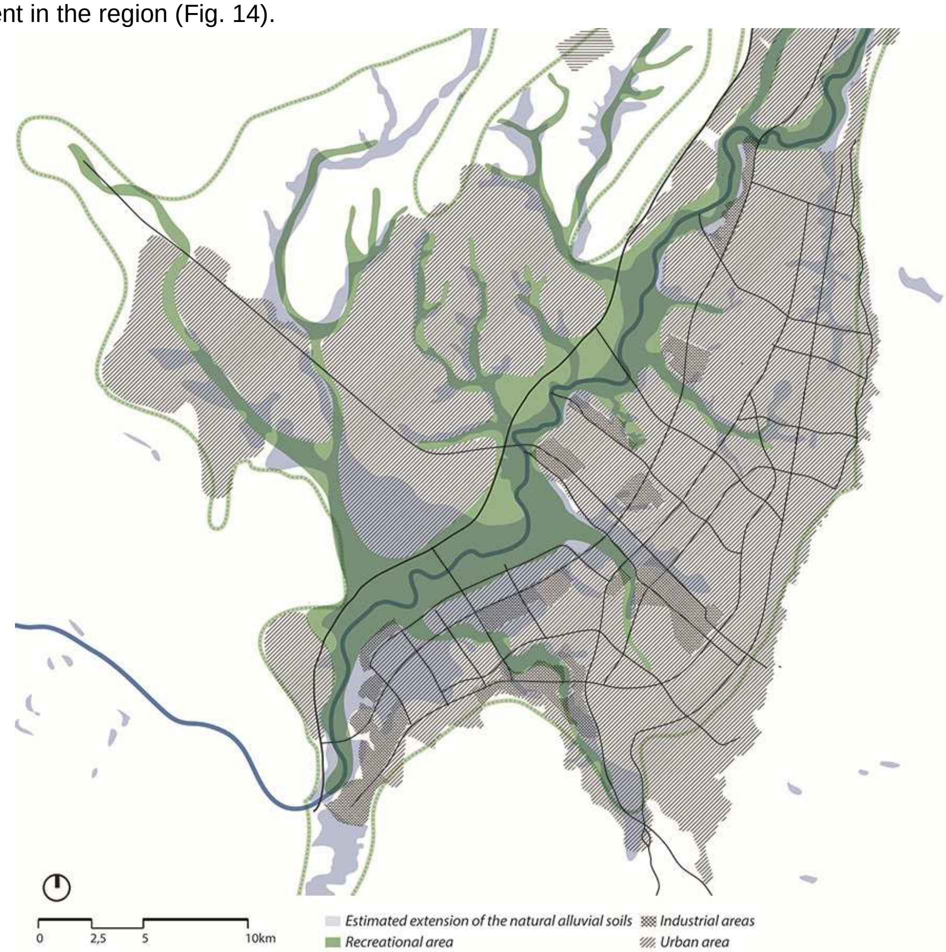

Fig. 14. Study of urban development patterns, water management plan 1973. (Estudio de aprovechamiento del Río Bogotá, 1973.)
Elaborated by the author based on CDM, 1973

Despite the richness of the study, the proposal limits to the re-profiling of the river section studying three alternatives for "improving" river flow capacity with 25 years flood return period (a) raising existing levees preserving the river course (b) building new levees 500 meters apart from each other to give space to the river (c) rectifying the river course building a new artificial canal with protection levees (CDM, 1973). The study also investigated soft alternatives for water management, for example retention lakes to manage peak flows, giving "room to the river" (alternative b), multifunctional floodplains. These innovative alternatives are common concepts today in the development of a resilient water-based urbanism that work with natural forces (Shannon, 2013). Unfortunately these alternatives were discarded because floods were not conceived in the "rational" idea of efficient, and the estimation of benefits was reduced to the amount of land for development. The negotiation between development pressures and ecological concerns has been one of the major challenges for the implementation of any water urbanism strategy.

The following proposals for the intervention in the Bogotá River continues the same lines of design. However the scope of the studies was clearly reduced, limiting the design to a definition of a profile and without actively integrating planning and water management. This studies are the result of a reactive response to the flood events of 1979 in which the limits of the intervention were clearly restricted by economic constrains and there was an urgent need to protect the informal settlements located in the floodplain[4]. The definition of the "normative riparian buffer" is also made in 1979. This buffer was a continuous parallel line to the river that standardized the floodplain width ignoring the landscape variations. The current "normative" floodplain follows to great extent this path.

4. CORRECTION OPERATIONS

4.1 Contemporary water management. From modern control to infrastructural breakdown and informal settlements upgrading

Despite State efforts to provide social housing, production was always below demand and the requirements to apply for housing programs forced families to look for solutions in the informal market. Informal areas grew exponentially, 7.5% of the urban growth during the decade of the 1960s, 6.4% in the 1970s, 8.6% in the 1980s and 20.3% in the 1990s and 2000s (SDP, 2007) (Fig. 15). The delimitation of the sanitary perimeter of 1962, probably influenced the location of informal settlements because it defined areas outside "formal" control, which coincide almost always with vulnerable land. This condition led to the concentration of low income populations outside the boundary of the sanitary perimeter which enforces social exclusion.

After 1970s there was an important interest from the State to support, upgrade and regularize the most precarious informal settlements. This approach was influenced by different international investigations (Turner, Alexandre, Caminos; MIT, CINVA) that revealed the potential of these settlements and the own building capacity of low-income groups (Torres 2011). Urban upgrading was also conceived as a control mechanism in response to the belief that informal settlements could endanger political stability. Therefore these programs channeled State and international investment (Banco Mundial, BIRF, USAID) (Torres, 2011).

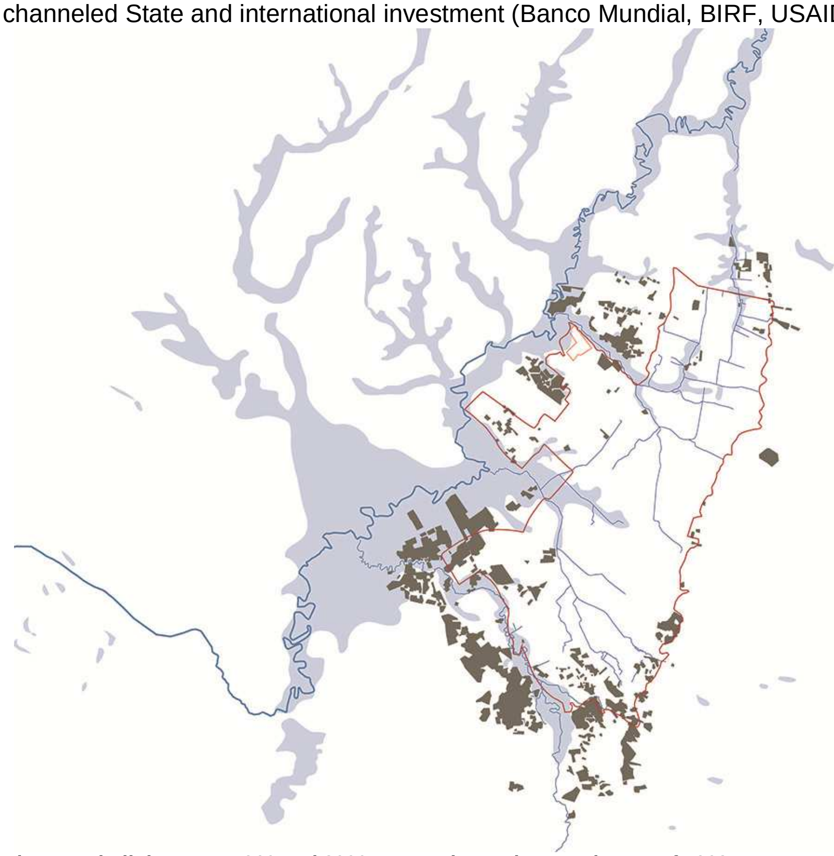

Fig. 15. Informal settlements built between 1960 and 2000 versus the sanitary perimeter of 1962
Elaborated by the author based on CDM, 1962; Jimenez; 2007

[4] The first of these studies was "Estudios de profundización del Río y ampliación y construcción de jarillones. (1980-1984)" developed by Gomez Cajiao y Asociados defined the main changes to the river course, shortening the river 15 kilometers by cutting seven meanders (CAR, 1981). The following study of 1985 by Hidroestudios and Black & Veatch, preserved the outline of the river course and focus in increasing the flow capacity of the profile. The particularity of this profile is its asymmetrical design. The levels of protection were linked to land use. In the eastern area it was proposed to fill the lowlands and build a new dike, in the eastern bank the existing terrain was preserved by this way discouraging urban development in this side (Black & Veatch, 1985).

During this period public policies were directed towards coping with the huge demand for public services such as water, sanitation and transportation, but there was not an overall concept about the green structure in spatial terms or the role of water beyond a functional necessity. Accordingly, urban planning focused on economic growth and illegal settlements control. The main two territorial ordinances that defined zoning codes and building regulations were Agreement 7-1979 and Agreement 6-1990. The main action of these ordinances was the regulation of the market.

Until the beginning of 1980s water management intended to create robust infrastructure for the development of the modern city. However, it shifted according to the political framework to deal with the realities of the informal city. This approach boosted a second phase of water infrastructure projects. The project Bogotá IV focused in the extension of the main network of water supply in order to extend the service for a population of around 700.000 inhabitants and guarantee fresh water supply until 2010 for the whole city. The project comprises a series of very large scale infrastructures. Among them the San Rafael reservoir with capacity of 75 million cubic meter, the tunnel Chingazá of 9.1 kilometers long and 2,8 meters diameter to improve fresh water distribution, connection lines between the tunnel and the water tanks Silencio-Casablanca of 66 kilometers long, Silencio-Vitelma of 14 kilometers and Wiesner-Suba of 0.5 kilometers and the Tunjuelo waste water interceptor of 77km. Local sewer networks were also completed in informal neighborhoods inside or outside the sanitary perimeter. The construction of these works pushed forward policies of informal settlements legalization, especially after the government of Jaime Castro in 1992.

As mention before, there were not urban plans during this period but rather planning codes and zoning regulations. Infrastructure projects were developed in a sectorial way solving urgent necessities continuing the mono-technical approach to infrastructure. This approach in this period was framed in the assumption of nature as an unlimited resource to serve the man.

The problem of fresh water supply was almost completely solved by 1994. However, the sewer system covered only about 85%. The project Santa Fé I was proposed to solve this issue (Fig. 16). The project focus in the development of a new Sewer System Master Plan that basically complements the network built after the Master Plan of 1962. The project established different aims, (1) the reduction of vulnerability, including for first time the risk of “infrastructure breakdown”, thus the necessity to maintain large water supply lines and built alternative infrastructure, (2) the works to complete the sewer and drainage networks and pump stations, in existing areas but also for future peripheral areas with flood risk and (3) the extension of the water supply network for peripheral neighborhoods, (4) development of educational programs and environmental projects for wetland preservation, and population re-settlement (World Bank, 1995). One of the projects to control flood risk in peripheral areas is the drainage network of the El Tintal watershed which enabled the construction of large social housing projects (Hidroestudios, 1999).

The growth of informal settlements represented a final transition towards the loss of resilience of the natural system. Fist, by occupying flood-prone and landslide areas, the natural performance of the floodplain as a sponge is therefore transformed, from a water field into lineal elements. Second, because the urban morphology of informal settlements is characterized by a high building coverage, which greatly reduces infiltration. High densities also increase the volume of waste water to be managed. Under the logics of informal urbanization, very little open space is left after the urbanization process. The decrease of open space, green areas and tree coverage results in increased run-off.

The technical solutions for the reduction of this risk in flood prone areas are based on mechanized systems of water management. This dependence does not completely eliminate risk. Under this approach natural dynamics are mostly considered as a threat.

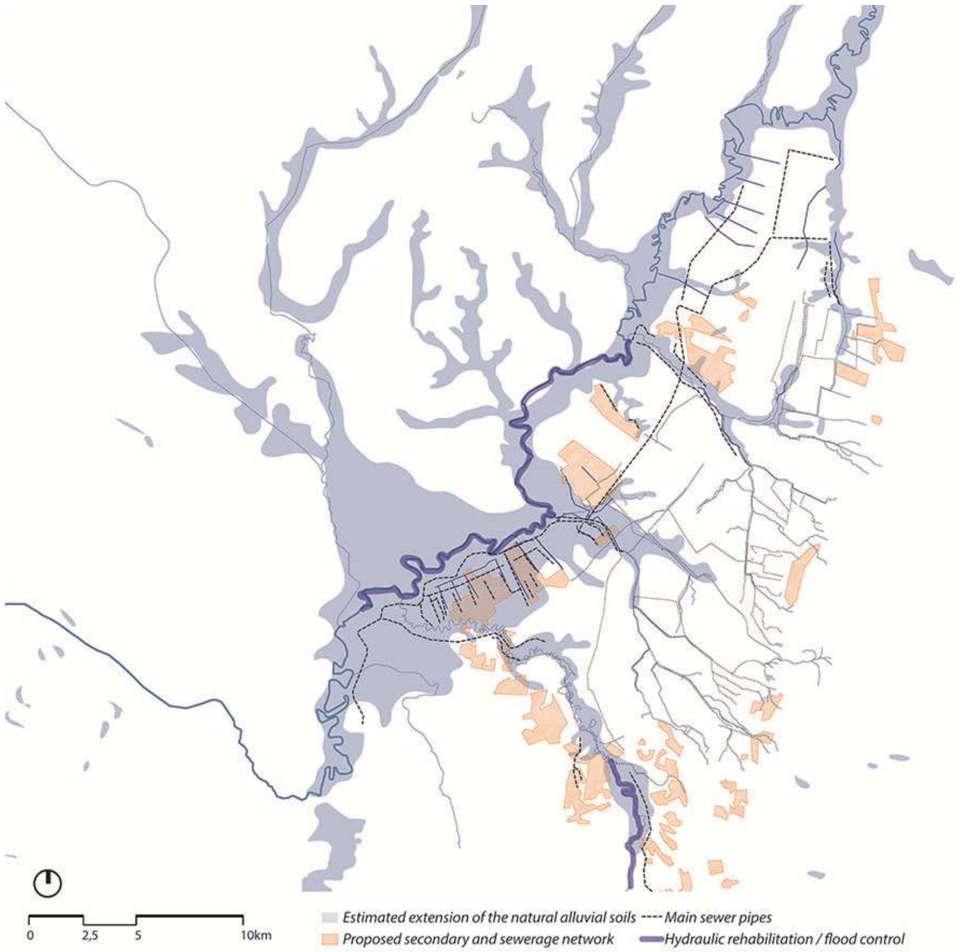

Fig. 16. Project Santa Fe I. Main sewer Network and neighborhoods for extension of drainage.
Elaborated by the author based on (World Bank, 1995)

- **Housing**

Another response to huge growth of informal areas is the development of Macro-projects of social housing. These housing projects responded to the creation of Metrovivienda in 1999, an agency that operates as public land bank. It provides serviced land on which private builders construct legal and affordable housing as to counter informality and increase dwelling quality. After several studies, Metrovivienda identified areas in the periphery that met the necessary conditions: cheap land prices, large plots and a small number of owners (Metrovivienda, 2011). Despite flood risks, Ciudadela El Recreo and El Porvenir, were selected to be developed as the first large social housing projects (Fig. 17).

The large scale of the project and its location directly on the floodplain made evident the intersection between water management and social housing. The technical solution is a linear system of open storm canals that work with a combination of pumps, preventing floods in new housing projects and the surrounding informal settlements. This infrastructure was included in the SantaFe I Project, and developed in detail in the Plan Maestro de Alcantarillado de la Cuenca El Tintal in 2000.

The urban layout of Ciudadela El Recreo was developed by Gustavo Perry, Konrad Brunner and Eduardo Samper (Fig. 18). It combine different housing typologies, mostly low rise single family houses and multifamily blocks. The organizing principle explores the potential of the grid crossed by a linear park, along one main storm water canal, in which the communal services, commercial areas and recreational facilities areas located (Samper & O´Byrne, 2012). Apart from the central green structure, the rest of the project is characterized by large impermeable surfaces. In 2011, after intense precipitation and lack of maintenance of the mechanized system, a major flood affected the area and its surroundings. This demonstrates the shortcoming of traditional, hard-engineering approaches and the need for context-responsive solutions to water management.

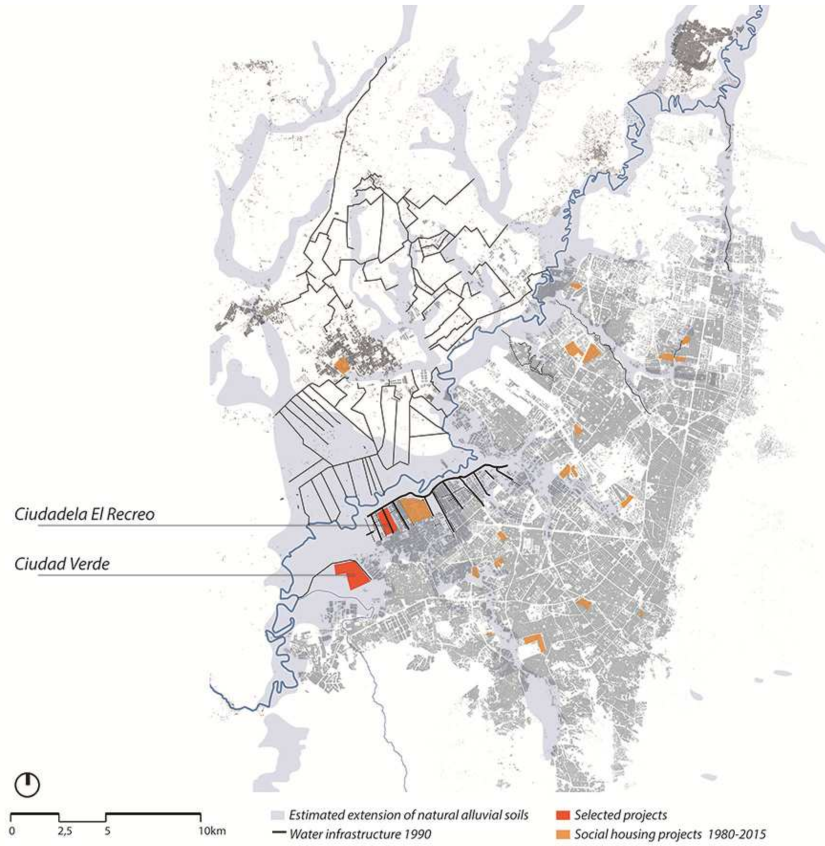

Fig. 17. Social Housing production and water system transformation 1990-2015.
Elaborated by the author based on Saldarriaga, 1996; Van Der Hammen 1998; Ideca 2015

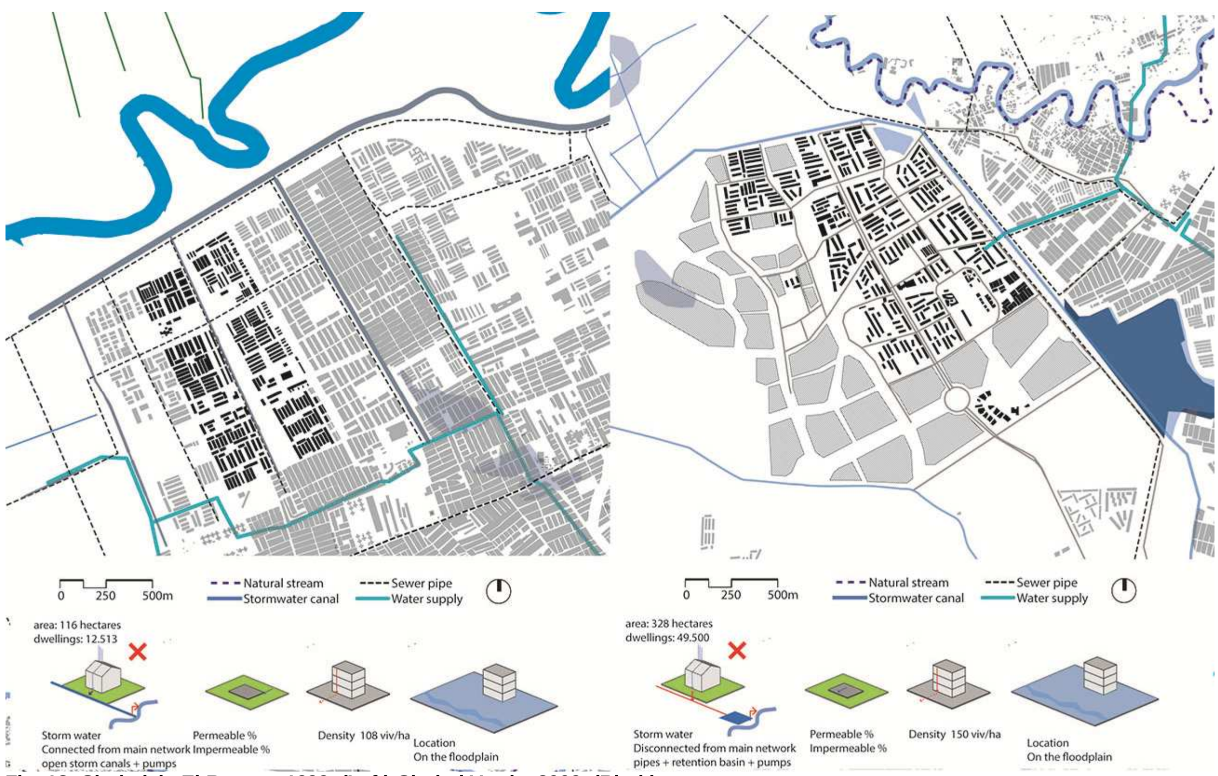

Fig. 18. Ciudadela El Recreo, 1999. (Left) Ciudad Verde, 2009. (Rigth)
Elaborated by the author.

5 TOWARDS ECOSYSTEMS IN THE MITIGATION OF ENVIRONMENTAL THREATS

5.1 Ecological structure and the housing debate

Three major lines underline the current projects for water management in Bogotá. (1) The provision of sanitation by extending the sewer and water supply networks. (2) The concept of ecological structure, since water bodies are classified as ecological structure water management encompasses both hydraulic control and landscape strategies to create biodiversity and public spaces. (3) The concept of vulnerability not only in relation to the infrastructure but also in relation to climate change. This three concepts clearly exemplify the strategic reappearance of water in the urban development discourse, coming from the awareness that water is a crucial and irreplaceable natural element. Although the symbolic meaning of water is not necessarily being resurrected, the magnitude of the water crisis is establishing new socio-cultural relations with water (Shannon, 2013).

The current debate about the production of social housing is more complex. The Bogotá's POT 2013 (land use plans), developed during the administration of Gustavo Petro, proposed the re-densification of the central area in order to control the expansion over the agricultural lands and floodplains. The plan promoted social housing in central locations with access to work opportunities and services. However, land prices and market trends make challenging its implementation, which resulted in a low production of dwelling units. Initiatives fostering the social inclusion in central areas also encountered opposition from the middle and high-income dwellers. The application of the POT 2013 was suspended in 2014 and current legal urban regulations are based on the POT 2000 developed during the administration of Enrique Peñalosa. In 2015 Peñalosa was reelected as Bogotá's major. Within the ambitious plans proposed by the major is the construction of housing in areas with ecological value, the protected area "Reserva Thomas Van Der Hammen", the river banks of the Bogotá River and the area of Campo Verde, which is seasonally affected by floods .

Disregarding the complexity of the normative issues, and the opposition of different actors. The housing problem is already a regional problem. The restrictions of land and policies in Bogotá has displaced social housing production to surrounding municipalities. Ciudad Verde is the larger example of this trend (Fig. 18). Ciudad verde is managed by the private sector and framed in the policy of "Macroproyecto de Interés Social Nacional" (MISN) (Macroprojects of National Social Interest) that aimed at promoting the production of low-income housing through the rapid construction of infrastructure, the speeding up of legal procedures and the promotion of big scale projects. The project is located in the municipality of Soacha and has an area of 327.9 hectares for 49.500 dwelling units.

The project is conceived as a self-sufficient town with a mixture of uses of different scales including the necessary facilities for an expected population of 200.000 inhabitants. Since the project is located in a flood prone area, water management included mitigation measures that are mainly the heightening of existing dikes along agricultural canals and the construction of a separated storm water drainage with a series of retention basins and pump stations (Amarilo, 2010).

6 CONCLUSIONS

The transformation of the natural water system can be summarized in four spatial interventions. First, in the central area at the beginning of the 1940s, the construction of a combined water management system transformed the rivers in underground sewer pipes. Second, between 1960 and 1970, the construction of a separated sewer system transformed the rivers in concrete open storm canals and an additional layer of underground waste-water sewer pipes appeared. Third, after 1990s the construction of a network of canals to manage storm water in the lowlands transformed the floodplain in a linear network of canals. In a parallel way, the irrigation district built after 1940s increased the productivity of the agricultural lands. The water supply network follows the road network revealing the artificiality of the grid, in which water is distributed from the mountains to each plot. The sewer network mostly follows the lines of the natural drainage network being completely depended on the logics of landscape. Rather than an artificial network is the transformation of the natural system in an infrastructure.

Pierre Belanger has pointed out to the necessity to make visible the flows, processes and systems that underlie urban economies (Belanger, 2010). The existing layer of water infrastructure is the result of a long process of negotiation between engineering design, planning, technical innovation, and economic constrains. This layer also determine the way in which water is metabolized by the city being instrumental to re-define the water cycles. Since the beginning of the 1900s a series of water management plans were developed to create the infrastructure that today supports the structure of the city. A new paradigm in water management appeals for a "soft engineering" approach that manipulates the existing layer of water infrastructure according to natural processes and urban dynamics as well new ways to anchor development to this hybrid infrastructural system (Shannon, 2013). Furthermore, a regional response to the housing problem requires new interplays between landscape, infrastructure and urbanization that recognizes the logics of the site (Shannon, 2013).

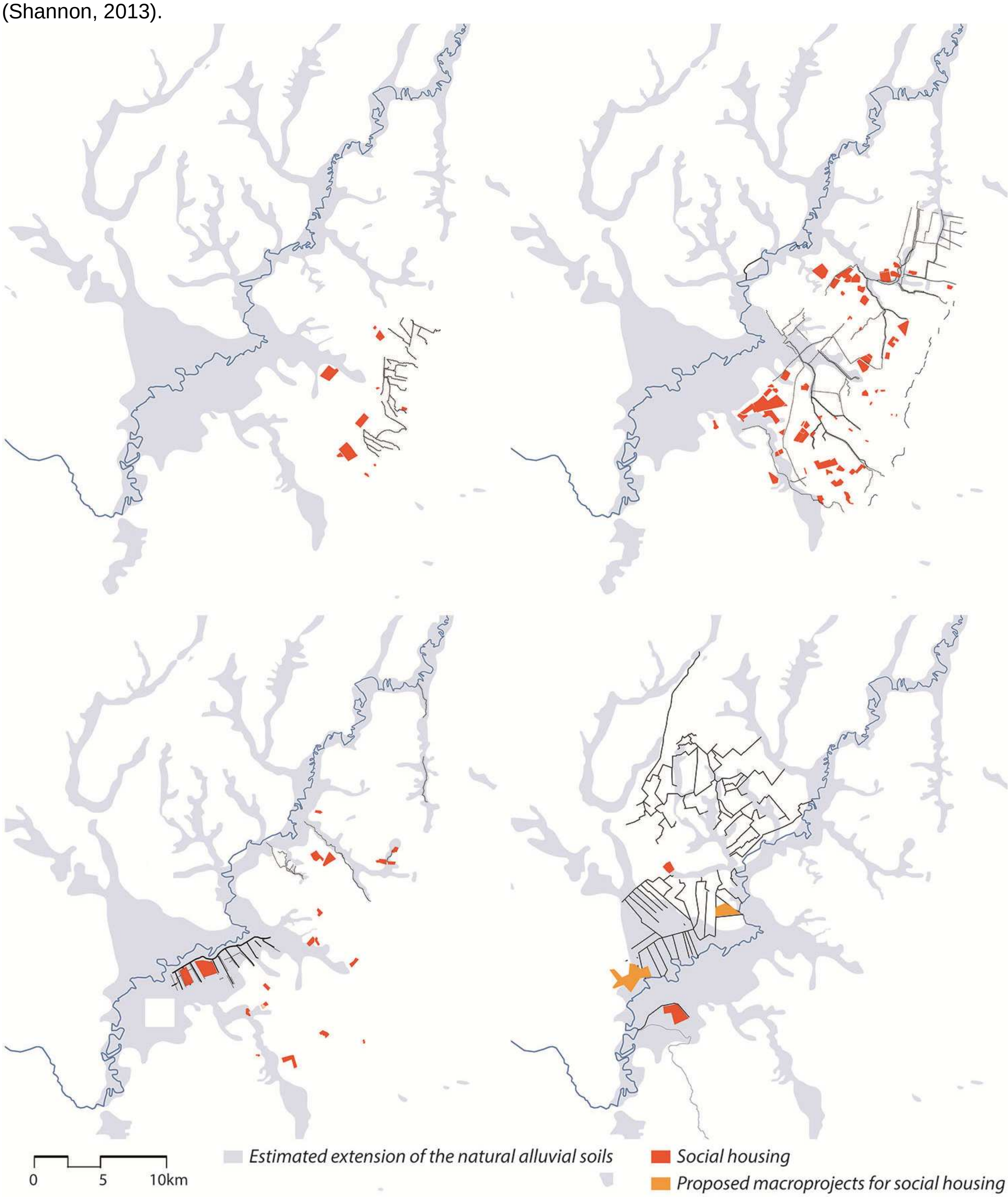

Fig. 19. Social Housing in relation to the transformation of the water system 1940-1970-1990-2015
Elaborated by the author based

Social housing production was built without an overall plan and is the result of a sum projects built by different institutions which explored changing urban design concepts and different management models. The location of the projects was directly influenced by the definition of the “sanitary perimeter” that guaranteed access to infrastructure and corresponded to safe land. After 1990s the intentions to urbanize the floodplain, coupled with the expansion of the administrative boundary and the already built informal settlements, pushing the urbanization of the floodplain. During the last decades macro-projects for social housing were proposed in the agricultural lands over the irrigation network.

The historical analysis of the water system transformation revealed that even during modernity, water structures were the keystones of urban construction. The definition of the city as shaped by water has been a cornerstone of urban design (De Meulder & Shannon, 2008). Rivers were central structuring elements in the urban plans of Brunner and Le Corbusier. Even water management plans from the 1970s evaluated the implementation of what can be called soft-engineered strategies. However the market driven approach of the definition of water /or / land in relation to property, economic constrains and social realities continue to challenge the implementation of water urbanism strategies.

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